

WHAT IS CLAIMED IS:

- 1 1. A 4-way power splitter/combiner circuit for use with power amplifiers, comprising:
  - 2 a splitter circuit, further comprising
    - 3 an input port;
    - 4 a first node;
    - 5 a second node;
  - 6 a first splitter transmission line having an impedance  $Z_{S1}$  and an electrical length  $\Phi_{S1}$ ,  
7 said first splitter transmission line for connecting said input port to said first node;
  - 8 a second splitter transmission line having an impedance  $Z_{S2}$  and an electrical length  
9  $\Phi_{S2}$ , said second splitter transmission line for connecting said input port to said  
10 second node;
  - 11 a first amplifier input;
  - 12 a second amplifier input;
  - 13 a third amplifier input;
  - 14 a fourth amplifier input;
  - 15 a third splitter transmission line having an impedance  $Z_{S3}$  and an electrical length  $\Phi_{S3}$ ,  
16 said third splitter transmission line for connecting said first node to said first  
17 amplifier input;
  - 18 a fourth splitter transmission line having an impedance  $Z_{S4}$  and an electrical length  
19  $\Phi_{S4}$ , said fourth splitter transmission line for connecting said first node to said  
20 second amplifier input;
  - 21 a fifth splitter transmission line having an impedance  $Z_{S5}$  and an electrical length  $\Phi_{S5}$ ,  
22 said fifth splitter transmission line for connecting said second node to said third  
23 amplifier input;

24        a sixth splitter transmission line having an impedance  $Z_{S6}$  and an electrical length  $\Phi_{S6}$ ,  
25            said sixth splitter transmission line for connecting said second node to said fourth  
26            amplifier input;  
27        a combiner circuit, further comprising  
28            an output port;  
29            a third node;  
30            a fourth node;  
31        a first combiner transmission line having an impedance  $Z_{C1}$  and an electrical length  
32             $\Phi_{C1}$ , said first combiner transmission line for connecting said output port to said  
33            third node;  
34        a second combiner transmission line having an impedance  $Z_{C2}$  and an electrical length  
35             $\Phi_{C2}$ , said second combiner transmission line for connecting said output port to  
36            said fourth node;  
37            a first amplifier output;  
38            a second amplifier output;  
39            a third amplifier output;  
40            a fourth amplifier output;  
41        a third combiner transmission line having an impedance  $Z_{C3}$  and an electrical length  
42             $\Phi_{C3}$ , said third combiner transmission line for connecting said third node to said  
43            first amplifier output;  
44        a fourth combiner transmission line having an impedance  $Z_{C4}$  and an electrical length  
45             $\Phi_{C4}$ , said fourth combiner transmission line for connecting said third node to said  
46            second amplifier output;

47        a fifth combiner transmission line having an impedance  $Z_{C5}$  and an electrical length  
48               $\Phi_{C5}$ , said fifth combiner transmission line for connecting said fourth node to said  
49              third amplifier output;  
50        a sixth combiner transmission line having an impedance  $Z_{C6}$  and an electrical length  
51               $\Phi_{C6}$ , said sixth combiner transmission line for connecting said fourth node to said  
52              fourth amplifier output;  
53        wherein said first amplifier input and said first amplifier output together define a first  
54              amplifier port, said second amplifier input and said second amplifier output together  
55              define a second amplifier port, said third amplifier input and said third amplifier  
56              output together define a third amplifier port, and said fourth amplifier input and said  
57              fourth amplifier output together define a fourth amplifier port, each said amplifier port  
58              for receiving an amplifier;  
59        wherein said first amplifier port, said second amplifier port, said third amplifier port and  
60              said fourth amplifier port collectively accept one to four amplifiers; and  
61        wherein the phase shift of each of said combiner transmission lines and each of said  
62              splitter transmission lines is selected to produce an in-phase signal at said output port.

1        2.        The 4-way power splitter/combiner circuit of claim 1 wherein the electrical lengths of  
2        said transmission lines satisfy the following equations:

$$\begin{aligned}3        \Phi_{S1} + \Phi_{S3} &= \Phi_{S1} + \Phi_{S4} = X; \\4        \Phi_{S2} + \Phi_{S5} &= \Phi_{S2} + \Phi_{S6} = Y; \\5        \Phi_{C1} + \Phi_{C3} &= \Phi_{C1} + \Phi_{C4} = X'; \\6        \Phi_{C2} + \Phi_{C5} &= \Phi_{C2} + \Phi_{C6} = Y'; \\7        |X - Y| &= |X' - Y'| = 90 \text{ degrees; and} \\8        (X - Y) &= (Y' - X').\end{aligned}$$

1       3.     The 4-way power splitter/combiner circuit of claim 1, further comprising at least one  
2     amplifier.

1       4.     The 4-way power splitter/combiner circuit of claim 3 wherein the impedance  
2     presented by said input port and said output port are between approximately 35 Ω and  
3     approximately 71Ω.

1       5.     The 4-way power splitter/combiner circuit of claim 3 wherein said at least one  
2     amplifier comprises a first amplifier in said second amplifier port.

1       6.     The 4-way power splitter/combiner circuit of claim 3 wherein said at least one  
2     amplifier comprises a first amplifier in said first amplifier port.

1       7.     The 4-way power splitter/combiner circuit of claim 6 wherein said at least one  
2     amplifier further comprises a second amplifier in said second amplifier port.

1       8.     The 4-way power splitter/combiner circuit of claim 7 wherein said at least one  
2     amplifier further comprises a third amplifier in said fourth amplifier port.

1       9.     The 4-way power splitter/combiner circuit of claim 7 wherein said at least one  
2     amplifier further comprises a third amplifier in said third amplifier port.

1       10.    The 4-way power splitter/combiner circuit of claim 9 wherein said at least one  
2     amplifier further comprises a fourth amplifier in said fourth amplifier port

1       11.    A 4-way power splitter/combiner circuit for use with power amplifiers, comprising:

2       an input port;

3       a first splitter transmission line connecting a first amplifier input to a first splitter node,  
4       said first splitter transmission line comprising a first splitter impedance transformer  
5       segment having impedance of 59.46 Ω and electrical length of 90° and a first splitter  
6       phase matching segment having impedance of 50 Ω and electrical length of 270°;

7       a second splitter transmission line connecting a second amplifier input to said first splitter  
8       node, said second splitter transmission line comprising a second splitter impedance

9           transformer segment and a second splitter phase matching segment, each of said  
10          second splitter impedance transformer segment and said second splitter phase  
11          matching segment having impedance and electrical length substantially identical to  
12          that of said first splitter impedance transformer and said splitter first phase matching  
13          segment;  
14          a third splitter transmission line connecting a third amplifier input to a second splitter  
15          node, said third splitter transmission line having impedance of  $50 \Omega$  and electrical  
16          length of  $180^\circ$ ;  
17          a fourth splitter transmission line connecting a fourth amplifier input to said second  
18          splitter node, said fourth splitter transmission line having impedance and electrical  
19          length substantially identical to that of said third splitter transmission line;  
20          a fifth splitter transmission line connecting said second splitter node to said input port,  
21          said fifth splitter transmission line comprising a third splitter impedance transformer  
22          segment having impedance of  $38 \Omega$  and electrical length of  $90^\circ$ , and a fourth splitter  
23          impedance transformer segment having impedance of  $64 \Omega$  and electrical length of  
24           $90^\circ$ ;  
25          a sixth splitter transmission line connecting said first splitter node to said input port, said  
26          sixth splitter transmission line having impedance of  $50 \Omega$  and electrical length of  $90^\circ$ ;  
27          an output port;  
28          a first combiner transmission line connecting a first amplifier output to a first combiner  
29          node, said first combiner transmission line comprising a first combiner impedance  
30          transformer segment having impedance of  $59.46 \Omega$  and electrical length of  $90^\circ$  and a  
31          first combiner phase matching segment having impedance of  $50 \Omega$  and electrical  
32          length of  $90^\circ$ ;

33 a second combiner transmission line connecting a second amplifier output to said first  
34 combiner node, said second combiner transmission line comprising a second  
35 combiner impedance transformer segment and a second combiner phase matching  
36 segment, each of said second combiner impedance transformer segment and said  
37 second combiner phase matching segment having impedance and electrical length  
38 substantially identical to that of said first combiner impedance transformer and said  
39 combiner first phase matching segment;  
40 a third combiner transmission line connecting a third amplifier output to a second  
41 combiner node, said third combiner transmission line having impedance of  $50 \Omega$  and  
42 electrical length of  $180^\circ$ ;  
43 a fourth combiner transmission line connecting a fourth amplifier output to said second  
44 combiner node, said fourth combiner transmission line having impedance and  
45 electrical length substantially identical to that of said third combiner transmission  
46 line;  
47 a fifth combiner transmission line connecting said second combiner node to said output  
48 port, said fifth combiner transmission line comprising a third combiner impedance  
49 transformer segment having impedance of  $38 \Omega$  and electrical length of  $90^\circ$ , and a  
50 fourth combiner impedance transformer segment having impedance of  $64 \Omega$  and  
51 electrical length of  $90^\circ$ ;  
52 a sixth combiner transmission line connecting said first combiner node to said output port,  
53 said sixth combiner transmission line having impedance of  $50 \Omega$  and electrical length  
54 of  $90^\circ$ ;  
55 wherein said first amplifier input and said first amplifier output together define a first  
56 amplifier port for receiving an amplifier, said second amplifier input and said second  
57 amplifier output together define a second amplifier port for receiving an amplifier,

58       said third amplifier input and said third amplifier output together define a third  
59       amplifier port for receiving an amplifier, said fourth amplifier input and said fourth  
60       amplifier output together define a fourth amplifier port for receiving an amplifier; and  
61       wherein 1-4 power amplifiers may be inserted in said amplifier ports to provide an  
62       amplified signal.

1       12.      A 4-way power splitter/combiner circuit for use with power amplifiers, comprising:  
2            a splitter circuit, further comprising  
3              an input port;  
4              a first node;  
5              a second node;  
6              a first splitter transmission line for connecting said input port to said first node;  
7              a second splitter transmission line for connecting said input port to said second node;  
8              a first amplifier input;  
9              a second amplifier input;  
10          a third amplifier input;  
11          a fourth amplifier input;  
12          a third splitter transmission line for connecting said first node to said first amplifier  
13          input;  
14          a fourth splitter transmission line for connecting said first node to said second  
15          amplifier input;  
16          a fifth splitter transmission line for connecting said second node to said third amplifier  
17          input;  
18          a sixth splitter transmission line for connecting said second node to said fourth  
19          amplifier input;  
20          a combiner circuit, further comprising

21       an output port;  
22       a third node;  
23       a fourth node;  
24       a first combiner transmission line for connecting said output port to said third node;  
25       a second combiner transmission line for connecting said output port to said fourth  
26       node;  
27       a first amplifier output;  
28       a second amplifier output;  
29       a third amplifier output;  
30       a fourth amplifier output;  
31       a third combiner transmission line for connecting said third node to said first amplifier.  
32       output;  
33       a fourth combiner transmission line for connecting said third node to said second  
34       amplifier output;  
35       a fifth combiner transmission line for connecting said fourth node to said third  
36       amplifier output;  
37       a sixth combiner transmission line for connecting said fourth node to said fourth  
38       amplifier output;  
39       wherein said first amplifier input and said first amplifier output together define a first  
40       amplifier port, said second amplifier input and said second amplifier output together  
41       define a second amplifier port, said third amplifier input and said third amplifier  
42       output together define a third amplifier port, and said fourth amplifier input and said  
43       fourth amplifier output together define a fourth amplifier port, each said amplifier port  
44       for receiving an amplifier;  
45       wherein said splitter/combiner circuit accepts one to four amplifiers; and

46 wherein said splitter transmission lines and said combiner transmission lines have a  
47 plurality of electrical lengths; and  
48 wherein the electrical lengths of each of said combiner transmission lines and each of said  
49 splitter transmission lines are selected to produce an in-phase signal at said output  
50 port.

1 13. The 4-way power splitter/combiner circuit of claim 12 further comprising an  
2 amplifier.

1 14. The 4-way power splitter/combiner circuit of claim 13 wherein said amplifier is  
2 populated in said first amplifier port.

1 15. The 4-way power splitter/combiner circuit of claim 13 wherein said amplifier is  
2 populated in said second amplifier port.

1 16. A 4-way power splitter/combiner circuit for use with power amplifiers, comprising:  
2 a splitter circuit, further comprising  
3 an input port;  
4 a splitter node;  
5 a first amplifier input;  
6 a second amplifier input;  
7 a third amplifier input;  
8 a fourth amplifier input;  
9 a first splitter transmission line having an impedance and an electrical length, said  
10 first splitter transmission line for connecting said input port to said splitter node;  
11 a second splitter transmission line having an impedance and an electrical length, said  
12 second splitter transmission line for connecting said splitter node to said first  
13 amplifier input;

14        a third splitter transmission line having an impedance and an electrical length, said  
15        third splitter transmission line for connecting said splitter node to said second  
16        amplifier input;  
17        a fourth splitter transmission line having an impedance and an electrical length, said  
18        fourth splitter transmission line for connecting said input port to said third  
19        amplifier input;  
20        a fifth splitter transmission line having an impedance and an electrical length, said  
21        fifth splitter transmission line for connecting said input port to said fourth  
22        amplifier input;  
23        a combiner circuit, further comprising  
24        an output port;  
25        a combiner node;  
26        a first amplifier output;  
27        a second amplifier output;  
28        a third amplifier output;  
29        a fourth amplifier output;  
30        a first combiner transmission line having an impedance and an electrical length, said  
31        first combiner transmission line for connecting said output port to said combiner  
32        node;  
33        a second combiner transmission line having an impedance and an electrical length,  
34        said second combiner transmission line for connecting said combiner node to said  
35        first amplifier output;  
36        a third combiner transmission line having an impedance and an electrical length, said  
37        third combiner transmission line for connecting said combiner node to said second  
38        amplifier output;

39           a fourth combiner transmission line having an impedance and an electrical length,  
40           said fourth combiner transmission line for connecting said output port to said third  
41           amplifier output;  
42           a fifth combiner transmission line having an impedance and an electrical length, said  
43           fifth combiner transmission line for connecting said output port to said fourth  
44           amplifier output;  
45           wherein said first amplifier input and said first amplifier output together define a first  
46           amplifier port, said second amplifier input and said second amplifier output together  
47           define a second amplifier port, said third amplifier input and said third amplifier  
48           output together define a third amplifier port, and said fourth amplifier input and said  
49           fourth amplifier output together define a fourth amplifier port, each said amplifier port  
50           for receiving an amplifier;  
51           wherein said splitter/combiner circuit accepts one to four amplifiers; and  
52           wherein the electrical length of each of said combiner transmission lines and each of said  
53           splitter transmission lines is selected to produce an in-phase signal at said output port.

1       17.     The 4-way power splitter/combiner circuit of claim 16 further comprising an  
2       amplifier.

1       18.     The 4-way power splitter/combiner circuit of claim 17 wherein said amplifier is  
2       populated in said first amplifier port.